A STUDY OF VENTRICULAR CONTRACTILITY AND OTHER PARAMETERS POSSIBLY RELATED TO VASODEPRESSOR SYNCOPE

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INTRODUCTION

Diminished orthostatic and exercise tolerance are common sequelae of relatively short periods of weightlessness.[1-3] Similar changes occur as a result of prolonged bedrest. Prior studies in this laboratory have delineated in detail many of the physiologic and metabolic changes that occur when bedrest is used as an analog of weightlessness. During the initial 24 - 48 hours of bedrest a large saluresis with accompanying water diuresis occurs as a result of a decrease in aldosterone production.[4] This saluresis and diuresis persists to a lesser extent throughout bedrest. The result is a decrease in plasma volume and extracellular fluid volume. The magnitude of the decrease is virtually as great after 24 hours as after four weeks of bedrest.[4] There is also an apparent decrease in body muscle mass which is revealed by significant losses of nitrogen and potassium and by a decrease in total body water without a corresponding decrease in body weight.[4]

Following bedrest of intervals as short as two weeks, distinct hemodynamic alterations are seen when volunteers are subjected to orthostatic and exercise testing. During 70° tilt testing, stroke volume drops to significantly lower levels than prior to bedrest and in spite of significantly higher heart rates, cardiac output falls to significantly lower levels.[5,6] These changes are accompanied by an incidence of syncope or presyncope that is about 20% higher after four weeks of bedrest.[4] Orthostatic tolerance returns to pre-bedrest levels by 2-7 days after re-ambulation in most subjects. This return of orthostatic tolerance appears to occur as a result of restoration of plasma and extracellular fluid volume to pre-bedrest

levels within a week of re-ambulation. The latter is brought about by a large increase in aldosterone production during the first days of re-ambulation and the associated retention of sodium and water.[4]

Decreased exercise tolerance resulting from bedrest is clearly measurable after only two weeks of bedrest. When subjects were tested by supine bicycle ergometry, stroke volume did not rise significantly above resting values at 50 Watts exercise whereas a significant rise was seen before bedrest. Heart rate showed highly significant increases after bedrest, but this was insufficient to raise cardiac output to levels achieved prior to bedrest.[5,6] Furthermore, derived maximal oxygen uptake was found to decrease after four weeks and subsequently after two weeks of bedrest.[4,7] This change did not return to pre-bedrest levels in conjunction with plasma volume restoration. In contrast, it required two weeks of ambulation for restoration to pre-bedrest levels. In fact, sixteen of twenty-four subjects who were at bedrest for four weeks had not achieved pre-bedrest levels at the end of two weeks of re-ambulation.[4] Similar decreases in maximal oxygen uptake resulting from bedrest have been noted by Saltin, et al.[8]

The above findings point to differences in the etiologies of orthostatic and exercise intolerance after bedrest, and by inference, after weightlessness. Whereas the decrease in orthostatic tolerance appears largely related to diminished vascular filling and inadequate venous return, the more prolonged decrease in exercise tolerance and the findings noted suggest that bedrest also decreases myocardial function.

However, the relationship between circulating blood volume and

physical fitness is complex. Danzinger and Cumming[9] demonstrated decreased maximal oxygen uptake in normal subjects made hypovolemic by chlorthiazide administration, and found this effect to be reversible with intravenous dextran. Contradictory evidence is given by Saltin[10] who indicated that no change in maximal oxygen uptake or cardiac output was effected by thermal dehydration in a group of normal subjects. Holmgren, et al[11] reported a strong correlation between work capacity, level of physical training, and total blood volume. The same correlation had previously been suggested by Kjellberg.[12] A more recent and contrary position is held by Robinson, et al[13] whose carefully conducted study could demonstrate no increase in maximal oxygen consumption or cardiac output in six normal men as a result of intravenous whole blood infusion during maximal upright exercise. At heart rates existent during maximal or near maximal exercise the diastolic filling period of the heart is decreased.[14] Thus, the influence of vascular filling is minimal at these heart rates, maximal oxygen uptake and cardiac output being limited primarily by the inotrophic state of the myocardium and the completeness of systolic emptying.

To summarize, even though supine cardiac output is known to be greater than upright cardiac output at rest and during submaximal exercise,[15] at maximal work loads, the main determinant of performance is the inotrophic state of the heart.[13] Similarly, it may be reasoned that the hypovolemia of bedrest (and weightlessness) is not the cause of the concomitant decrease in maximal exercise capability. Consistent with this view, Stephens, et al[16] were unable to

prevent bedrest-induced decreases in maximum oxygen consumption by application of lower body negative pressure, despite full restoration of blood volume by that device, again suggesting the possibility of diminished myocardial function after bedrest.

The present study was undertaken in an attempt to approach more directly the question of whether alterations in myocardial contractility are induced by bedrest (or weightlessness). The standard measurements of contractility require left ventricular catheterization,[17] and proof of bedrest alterations would require such studies to be performed on two occasions. For ethical reasons left ventricular catheterization of normal volunteers was excluded from consideration. Instead, three non-invasive methods were chosen. These were: apexcardiography (ACG), systolic time intervals (STI), and echocardiography. The validity of the three methods of determining myocardial contractility used in the present study rest upon evidence of correlation with internally derived indices of contractility such as ejection fraction, V_{max}, maximum dP/dt, left ventricular end-diastolic volume and pressure, stroke-work index, etc.

APEXCARDIOGRAPHY

In recent years a number of papers have been published relating the ACG to the hemodynamic status of the heart. Findings in the ACG assist in identifying events in the phonocardiogram.[18-23] Measurement of the ACG "a" wave is a useful estimate of left ventricular end-diastolic pressure and mean left atrial pressure,[24,25] and the presence of congestive failure.[26-29] Qualitative trends in the ACG are manifested by such entities as left ventricular hypertrophy,[30] myocardial assynergy,[31-33] idiopathic hypertrophic subaortic stenosis,[34]

myocardial infarction,[35-37] left atrial disease,[38-40] and right ventricular hypertrophy.[41-42] Study of the rapid filling wave[43-45] is promising as a non-invasive means of measuring left ventricular compliance. Few studies have been published which define the ACG in terms of absolute displacement.[33,39,46] This is largely because of the difficulty in calibrating transducers to quantify displacement of the ACG from some theoretical baseline, as well as difficulty in defining what is normal by that method. These problems have been obviated by quantitating the ACG according to ratios of related peaks in the tracing, and by measuring time intervals. Because of the close resemblance between the ACG and the left ventricular pressure curve, and between the first derivative of the ACG and the first derivative of that pressure, study of dA/dt (ACG first derivative) has attracted interest since 1951.[47,48] The interval from the onset of ventricular depolarization to peak dA/dt (R-dA/dt) was shown by Reale[49] to correlate exactly with the interval from the onset of ventricular depolarization to the peak dP/dt (R-dP/dt). This latter is known to be an excellent indicator of cardiac contractility, unaffected by changes in preload and afterload.[50] Studies in this laboratory have shown that the value of R-dA/dt can differentiate among normal, hyperdynamic, and failing hearts.[51] Good correlation was found in 23 patients between R-dA/dt and catheterization indices of left ventricular function, such as ejection fraction, V_{max}, peak dP/dt, and left ventricular end-diastolic pressure and volume.

SYSTOLIC TIME INTERVALS

Of the methods used in the present study the STI have probably been the most extensively studied.[52-59] Over a decade ago, Weissler, et al

showed that the left ventricular ejection time (LVET) was fairly linearly related to stroke volume, and this relationship could be used to separate normal individuals from those with cardiac failure.[52] More recently the pre-ejection period (PEP), which can be subdivided into the Q-S_1 (onset of the QRS to onset of the first heart sound) and the isovolumic contraction time (ICT), was found to reflect changes in internally measured ICT.[54,59,60] The ratio PEP/LVET has been repeatedly correlated with ejection fraction as well as with contractile element velocity at peak isometric stress[61-65] and with the Frank-Levinson contractility indices.[63,64] In terms of functional significance, the STI have been shown to undergo characteristic alterations in acute myocardial infarction,[65] and in cardiac decompensation from a variety of causes.[52,54,56,61-63,65-67] The STI are predictably affected by the positive inotropic forces such as exercise,[58,68] digitalis,[55] and adrenergic stimulation.[66,69,70] While preload and afterload effects upon the STI are rather uncertain, Stafford, et al[71] found that either passive 90° head-up tilt or the application of tourniquets will increase PEP/LVET, thus suggesting that the left ventricular end-diastolic volume may be a determining variable. Ahmed[66] notes that an improved correlation with ejection fraction and V_{max} is achieved only when patients with valvular disease, shunts, and pulmonary disease are excluded from consideration.

ECHOCARDIOGRAPHY

The use of pulsed reflected ultrasound to examine the heart, echocardiography, is the most recent major external biosensor technique to be added to the cardiologic armamentarium. Early experience with

echocardiography quickly led to its present unique role in diagnosing pericardial and mitral valvular disorders.[72-74] The facility with which the posterior wall of the heart and its mean velocity in systole (PWV) have been determined by echocardiography has led to publication of data showing good correspondence of the PWV with velocity of circumferential fiber shortening.[75,76] Kraunz and Kennedy[75] found that both maximal posterior wall velocity and PWV were consistently increased by the positive inotropic effect of exercise, and were roughly correlated with heart rate. Studies by Rowyer, et al[77] and by Rushmer, et al[78] have indicated a close correlation between the posterior wall echogram and standard left ventricular volume curves. The relative effects of preload and afterload on, and the relationship of cardiac contractility to the posterior wall echogram have not as yet been firmly established. Further, the repeatability of the PWV needs more substantiation than is presently available in the literature.

METHODS

Subjects for the study were healthy male volunteers,* aged 20-29. They weighed 139.6 to 191.1 lbs (mean 161.2) and were 65 to 75 in. tall (mean 69.3). Upon admission to the Metabolic Ward, all subjects were given thorough medical evaluation and placed on a metabolically balanced diet, with a normal, fixed intake of sodium, described elsewhere.[4] Following an initial equilibration period of 7-10 days, a two week control period (C) preceded 28 days of absolute horizontal bedrest (B), which in turn was followed by a two week recovery phase (R). In general, studies were performed weekly during the control period,

*Recruited from the Federal Correctional Institution, Lompoc, Calif.

at the end of bedrest, and at the end of each subsequent week of recovery. Studies in some subjects were done at weekly intervals throughout all phases. In addition to study of patients undergoing four weeks of bedrest, a number of patients were studied under identical conditions while undergoing only two weeks of bedrest. These studies were performed to enable definition of early bedrest changes.

All procedures were performed about 8 A.M. in the Cardiac Catheterization Laboratory. The subjects were transported to the laboratory by guerny in the supine position, and were in the post-absorptive state.

Apexcardiography

With the subject rotated anywhere from 30° to 50° toward the left lateral decubitus position in an angiography cradle, the cardiac apex was located by fingertip palpation. A piezo-electric microphone (Electronics for Medicine Model PS-1B) was employed connected to the multiple band phono amplifier of a multichannel photographic recorder.** The amplifier range was set at 1 to 50 Hz. The microphone was held in its interspace by a circumferential elastic Velcro(R) strap. The first derivative of the apexcardiogram, dA/dt, was obtained by means of a resistance-capacitance network with a flat response in the range of 0 to 75 Hz. Tracings were made at paper speeds of 100 mm/sec with 0.1 sec vertical time lines. An electrocardiogram was recorded simultaneously, from a lead configuration which give a distinct Q-wave, and this same configuration was repeated for subsequent studies in each individual. The R-R interval preceding each cycle, and the interval R-dA/dt ("R" in this case meaning the onset of the QRS),

** Electronics for Medicine DR-16

were measured by averaging the values obtained from 12 cardiac cycles during normal respiration. A correction for the effect of heart rate was applied to the interval R-dA/dt by dividing it by the square root of the R-R interval (see Results). Prior to final analysis of results, the change in R-dA/dt/$\sqrt{\text{R-R}}$ after four weeks of bedrest in subjects receiving 9-alpha-fluorohydrocortisone was compared with the change seen in untreated volunteers. There was no significant difference and all data was, therefore, treated as a single homogeneous pool.

Systolic Time Intervals

The STI of the left ventricle were obtained by simultaneous recordings of the carotid pulse, phonocardiogram, and electrocardiogram. When possible, the STI were recorded simultaneously with the ACG and dA/dt. A piezo-electric microphone (Electronics for Medicine PS-13) with a 4 mm diameter cylindrical pickup was used with an amplifier channel of the multipurpose photographic system to obtain the carotid pulse wave form by placing the microphone over a carotid artery below the carotid sinus. A similar microphone with a diaphram-type pickup was used to record heart sounds in the 100 to 500 Hz range from a position along the left sternal border which gave maximum resolution of the two components of the second heart sound. The period of electromechanical systole, from the onset of the QRS to the aortic component of the second heart sound ($Q\text{-}S_2$) was determined along with the LVET, measured from the sharp upstroke of the carotid wave to the incisura. PEP was determined by the formula, PEP = $Q\text{-}S_2$ - LVET. Final values were obtained by meaning the results of twelve cardiac cycles during normal respiration. The ratio PEP/LVET were determined for all results.

The heart rate corrected indices of the STI, the Q-S_2I, LVETI and PEPI were calculated by the method of Weissler.(79) As in the case of R-dA/dt/$\sqrt{R\text{-}R}$, the changes in the ratio PEP/LVET of the subjects of the 9-alpha-fluorohydrocortisone treated group and the untreated group were determined at the end of the fourth week of bedrest. No significant difference was found and the data were pooled.

Echocardiography

With the subject in the supine position, ultrasonic determination of left ventricular wall motion was made using the Ekoline 20 Ultrasonoscope (Smith, Kline, and French Instrument Co.). This employs a 2.25 megacycle 3/4 in. transducer with a 10 cm focus which transmits 1 μsec ultrasonic impulses at a rate of 200/sec. The intracardiac structures were scanned in a sequential and repeatable foremat in an attempt to identify a specific echo window for recording posterior left ventricular wall motion. The method consists of placing the transducer in the fourth or fifth left intercostal space at the left sternal border. The transducer is angulated in a right superio-medial direction until characteristic echos of the ascending aorta are recognized in B mode scanning. The transducer is then directed inferolaterally until the mitral annulus and subsequently the mitral valve echoes are clearly identified. This motion of the transducer is continued until the mitral valve echo disappears and characteristic echo recordings of the cords and subsequently the papillary muscle are identified. The transducer is then ideally beamed at the area underneath the posterior leaflet of the mitral valve superior to the papillary muscle. The echo window is clearly and rapidly identified by an

experienced echocardiographer, and in most cases, high fidelity recordings of the posterior wall motion are recorded using analog gating techniques. Calibrations were made by moving the gate over the pure echo signal of a plexiglass block such that 1 cm of gate motion produced a 5 cm displacement of the recorded signal. Records were made by means of an Electronics for Medicine photographic recorder at paper speeds of 100 mm/sec. EKG was recorded simultaneously.

The magnitude of posterior wall excursion (PWE) was determined by measurement of the amplitude of the systolic excursion of the recorded posterior wall curve from baseline or end-diastolic position. The mean velocity of excursion (PWV) was found by measuring the angle that the slope of the line extending from the onset of systole to the peak of systolic movement makes with the baseline.[75] The tangent of this angle divided by the calibration factor and multiplied by 100 gave the PWV in cm/sec. High fidelity recordings were meaned from at least six cardiac cycles to derive the values. Since both PWE and PWV are related to myocardial contractile state, their product (PWV x PWE) was evaluated as an additional index.

In order to document the value of these measurements as indicators of the state of left ventricular function, they were compared with standard cardiac catheterization indices in 21 patients. These results as well as those of bedrest subjects will be presented.

Statistical Methods

All results were analyzed for statistical significance by the paired Student's "t" test. Standard techniques were used in determining correlation coefficients and standard errors.[80] Significance was presumed to exist for all values of $P < .05$.

RESULTS

Apexcardiography

Table 1 contains the results of measurement of R-R interval (heart rate), R-dA/dt, and values for R-dA/dt/$\sqrt{RR}$ for all subjects at the end of each indicated week of study. Figure 1 illustrates the measurement of R-dA/dt. In total, sixteen subjects were studied before and after four weeks of bedrest, and eight subjects before and after two weeks of bedrest. In each subject the results of the Control Week 2 (baseline) R-dA/dt measurements were correlated with R-R intervals, systolic and diastolic blood pressures, and plasma volumes existent at the time of the measurements (Table 2). Of these, only heart rate (R-R interval) was found to correlate with R-dA/dt ($r = 0.525$, $P < 0.01$). The regression line for the relationship between R-dA/dt (sec) and R-R interval (sec) is shown in Figure 2. This relationship is expressed for the 24 subjects studied by the formula: R-dA/dt = 0.629 (R-R) + 0.0266. In the analysis of bedrest effects on R-dA/dt it was necessary to correct for alterations in basal heart rate induced by bedrest and the resultant effects on R-dA/dt. This was accomplished by two separate approaches.

Firstly, all heart rates fell within the range of 40-120/minute (R-R interval 0.50 - 1.50 sec). In this range it is possible to correct all values for R-dA/dt to a value which would be existent at a heart rate of 60 (R-R = 1.0 sec) by dividing R-dA/dt by $\sqrt{R\text{-}R}$. This is possible because the relationship between $\sqrt{R\text{-}R}$'s for varying R-R intervals is essentially linear in the stated range. The results of this correction for heart rate (R-dA/dt/$\sqrt{R\text{-}R}$) are shown in Table 1

with the basic data. Tables 3-7 show the paired analysis of changes in heart rate, R-dA/dt, and R-dA/dt/$\sqrt{\text{R-R}}$ at the end of one week of bedrest (B1), two weeks of bedrest (B2), four weeks of bedrest (B4), and after two and three weeks of ambulant recovery (R2 and R3). The pertinent changes in R-dA/dt/$\sqrt{\text{R-R}}$ are summarized in Table 8, and presented graphically in Figure 3. It is apparent that significant prolongation of this measurement occurs by the end of the second week of bedrest ($P < 0.05$) and persists beyond the end of the second recovery week ($P < 0.02$). Beyond pure statistical results, this table also shows that by even one week of bedrest, four of six subjects have developed a prolonged R-dA/dt/$\sqrt{\text{R-R}}$. Similar evaluation shows 14 of 16 subjects (88%) with this alteration at the end of four weeks. After three weeks of recovery, only slightly more than one-half of subjects have returned to their pre-bedrest status.

Since the correction of the data to a common heart rate of 60/minute might be considered arbitrary, the regression equation (vide supra) relating R-R interval to R-dA/dt for this group of subjects was utilized to determine a predicted R-dA/dt for each subject on each day of study based upon his heart rate at the time of measurement. The predicted values were then compared with their paired experimentally measured values on each day of study. The results are shown in Table 9. Using this method of analysis, a prolongation in R-dA/dt beyond that due to a change in heart rate alone is seen at the end of one week of bedrest, becoming significant after two weeks ($P < 0.05$) and remaining significantly prolonged even at the end of three weeks of ambulant recovery ($P < 0.05$).

No correlation between R-dA/dt and plasma volume was noted in baseline measurements (Table 2). However, bedrest is well known to lower plasma volume. The magnitude of these decreases in plasma volume are unlikely to alter left ventricular pre-load in the supine subject. However, this possibility was analyzed. Tables 10-13 show the comparison of plasma volumes for each subject studied by apexcardiography at the end of bedrest weeks 1,2 and 4 and at the end of recovery week two with paired control values. The mean values for each group are shown in Table 14 and illustrated in Figure 4. The decrease in plasma volume becomes statistically significant at the end of two weeks of bedrest (B2, $P < 0.005$), and remains significant after four weeks (B4, <0.05) in spite of the effects of plasma volume expansion by 9-alpha-fluorohydrocortisone in four subjects. After two weeks of ambulant recovery plasma volume has returned to levels equivalent to those existent prior to bedrest.

The fact that the group changes in R-dA/dt/$\sqrt{\text{R-R}}$ and plasma volume do not correspond, at least during the recovery period, again suggests an independent change. To insure that no relationships existed, each individual's change in plasma volume was correlated with his change in R-dA/dt/$\sqrt{\text{R-R}}$ at the end of first, second, and fourth weeks of bedrest, and at the end of recovery week two (Tables 15-18). In no case was there any correlation.

Systolic Time Intervals

Table 18 summarizes the systolic time interval data on each day of study for ten subjects who underwent four weeks of bedrest and ten subjects who underwent two weeks of bedrest. The actual measurements

of R-R interval (heart rate), $Q\text{-}S_2$ interval (interval between onset of the QRS complex of the EKG and the onset of the aortic second heart sound), PEP (pre-ejection period), LVET (left ventricular ejection time), and the ratio PEP/LVET are given. Figure 1 illustrates the determination of these intervals. The corresponding values, corrected for heart rate, of $Q\text{-}S_2I$, LVETI and PEPI are also tabulated. Because of the small number of subjects in the present study, Weissler's regression equations were utilized for the heart rate corrections.(79) For the male, these are:

$$Q\text{-}S_2I = 2.1\ (HR) + Q\text{-}S_2$$

$$PEPI = 0.4\ (HR) + PEP$$

$$LVETI = 1.7\ (HR) + LVET$$

The ratio PEP/LVET encompasses changes in both PEP and LVET and appears to be a sensitive indicator or left ventricular function. Prior studies have shown it to be relatively uninfluenced by heart rate. In order to re-evaluate this question and to evaluate the potential effects of blood pressure (after load) and plasma volume (pre-load) alterations in the subjects of the current study, the baseline values of control Week 2 for PEP/LVET were correlated with existent heart rate (R-R interval), systolic and diastolic blood pressure, and plasma volume (Table 20). There was no correlation with any of these parameters.

Tables 21-25 tabulate the paired comparisons of R-R interval, $Q\text{-}S_2I$, LVETI, PEPI and PEP/LVET of the baseline values with bedrest weeks 1,2 and 4, and recovery weeks 2 and 3. No statistically significant and consistent pattern of change is seen in PEPI, LVETI, or $Q\text{-}S_2I$. The mean changes are depicted in Figure 5. The variable

statistical results may be the result of the small sample and the fact that the same subjects are not represented at each study period.

The results for PEP/LVET are perhaps more meaningful. As shown in Table 26, this ratio is increased over corresponding control values at all bedrest and recovery intervals. This increase is statistically significant at the end of bedrest week one ($P < 0.0025$), and week four ($P < 0.02$), and at the end of recovery week three ($P < 0.025$). At the end of bedrest week two and recovery week two, statistical significance is approached, but not achieved ($P < 0.1$). At all intervals, over 70% of subjects show an increase in PEP/LVET after being subjected to bedrest. The changes in PEP/LVET are illustrated graphically in Figure 6.

Tables 27-30 compare the plasma volumes of subjects on whom STI measurements were made at each study interval with their matched control plasma volumes. Results are summarized in Table 31 and presented graphically in Figure 7. The failure to show a statistically significant decrease in plasma volume at the end of four weeks of bedrest results from the fact that three of the ten subjects received 9-alpha-fluorohydrocortisone during the last week of bedrest. Individual changes in PEP/LVET and plasma volume at each point of the study are correlated in Tables 32-35. It is apparent that the alterations seen in PEP/LVET were not influenced by the changes in plasma volume induced by bedrest.

Echocardiography

Table 36 lists the diagnoses of the 21 patients in whom echocardiographic studies were correlated with results obtained at left ventricular catheterization. Fifteen intravascularly-derived

measurements of left ventricular function were correlated with the three echocardiographic parameters. Of the former, ejection fraction (EF), R-dP/dt (the time interval from the onset of the QRS to the peak velocity of left ventricular pressure rise), ICT (isovolumic contraction time - the interval from the onset of the QRS to the beginning of left ventricular ejection), and V_{max} are most associated with the intrinsic state of the heart or cardiac contractility; the remaining indices are perhaps more reflective of myocardial performance. Of all of these, ejection fraction is generally regarded as the best single index of overall ventricular function. The results of all measurements are shown in Table 37.

Echocardiographic correlations with the various indices and the significance of the correlations are given in Table 38. Quite apparent is that all three echogram indices correlated rather well with ejection fraction. PWE showed additional sssociations with S.V. (angio) (stroke volume by angiographic methods), LVET and ICT. When data are grouped according to the presence or absence of coronary artery disease (Table 39), the correlations with ejection fraction become polarized; extremely significant R values are obtained for the non-coronary group, while those of the coronary group lose significance altogether. These results with the coronary artery disease group are not unexpected. Cineangiography very often shows such patients to manifest ventricular akinesia and dyskinesia. The posterior wall echogram may in these cases have characteristics not at all representative of the myocardium as a whole.

On the basis of the promise offered by the above results, sequential

echocardiograms were obtained in seven normal subjects undergoing four weeks of bedrest, and three undergoing two weeks of bedrest. Results of measurement of PWE and PWV are shown in Tables 40 and 41. No attempt has been made to analyze this data statistically as it is so grossly variable as to preclude any possibility of significance testing.

DISCUSSION

The purpose of the present study was to determine whether or not bedrest, and by inference, weightlessness, decreases myocardial function. The latter possibility was suggested by the apparent prolongation of decreased exercise tolerance (as measured by maximal oxygen uptake) beyond the return of orthostatic tolerance after bedrest. It was further suggested by the decrease in ability to increase stroke and cardiac output during exercise after bedrest to levels seen prior to bedrest. Answers to this question could be quickly obtained by measurement of left ventricular function before and after bedrest by standard left heart catheterization techniques. However, for ethical and moral reasons the conduct of such studies on normal volunteers is not possible. Further, these methods could not be utilized on astronauts before and after space flight, so no comparisons between limited space flight and more extensive ground based studies could be made. For these reasons it was necessary to utilize non-invasive techniques to measure myocardial function in the present study.

As noted previously quantitative apexcardiography, systolic time interval measurements, and echocardiography have each been established

to be reliable means of determining the state of myocardial function non-invasively. In the clinical situation where one is comparing the results of measurements from diseased myocardiums with those from normal hearts, the differences are readily apparent. However, at the outset of the present study it was not possible to predict whether these methods would prove sufficiently sensitive to detect relatively subtle changes in the myocardial function of normal individuals. Had the study results been negative, it would not have been possible to declare the absence of diminished ventricular function, since negative results could have resulted from method insensitivity. In fact, the echocardiographic results illustrate this point. In the clinical subjects with diffuse myocardial disease, results of measurement PWE and PWV showed good correlation with ventricular function. In the bedrest subjects with normal heart size, no reproducible individual pattern of results was obtainable. The obvious reason for this problem relates to the inability to exactly pin-point the same myocardial echo window on each occasion. While this problem may not be insurmountable, it will require finite technical study. Changes in heart size, such as may occur as a result of plasma volume decreases, minor changes in body position and the like can result in an altered echo window no matter how carefully structures are identified.

In contrast to echocardiography, measurement of the interval R-dA/dt and measurement of systolic time intervals are not dependent upon isolating and reproducing a small area of myocardium for repeated evaluation. These measurements, which are more related to velocity

and duration of total left ventricular contraction, appear more well suited for longitudinal or sequential studies such as the present one. The planned simultaneous use of both methods has the distinct advantage of providing confirmatory evidence of alteration. In addition, technical problems may be encountered with either method with resultant loss of data. In some cases no adequate apexcardiogram can be obtained due to a muscular chest wall or increased anterior-to-posterior diameter of the chest. Further, shattering of the dA/dt trace occasionally makes interpretation difficult. In normal individuals it is unusual to be unable to obtain the recordings necessary to determine STI's. The prime problem here is in obtaining a well-defined carotid pulse trace.

In the evaluation of the results of the current study, a number of factors which are known to have an effect on ventricular function were considered. These included: heart rate; pre-load; after-load; and inotrophic state. Heart rate is known to influence STI's except the ratio PEP/LVET and appropriate corrections were made.[79] Our results confirm the lack of correlation between PEP/LVET and heart rate. In contrast, a definite correlation between heart rate and the interval R-dA/dt has been demonstrated. However, the changes seen as a result of bedrest have been clearly shown to be independent of changes in heart rate brought about by bedrest.

In the present study, all measurements were made in the supine position, and it was unlikely that the alterations in plasma volume that occurred in the volunteers studied would affect pre-load. Confirmation of a lack of effect was clearly shown by the failure of baseline

R-dA/dt/$\sqrt{R\text{-}R}$ and PEP/LVET measurements to correlate with baseline plasma volume values. Further, when changes in plasma volume at the various points of study were compared with simultaneous changes in the above measurements, no correlation was found. The fact that prolongation in R-dA/dt/$\sqrt{R\text{-}R}$ and PEP/LVET was not prevented in those subjects whose bedrest induced plasma volume decrease was reversed by treatment with 9-alpha-fluorohydrocortisone also points to the lack of relationship between these parameters and plasma volume change. In addition, our prior studies have clearly shown plasma volume to return to pre-bedrest levels by one week of ambulant recovery.[4] In contrast, R-dA/dt/$\sqrt{R\text{-}R}$ and PEP/LVET require 2-3 weeks or longer for restoration, thus corresponding to the previously noted changes in maximal oxygen uptake.[4]

There was also no correlation between systolic or diastolic blood pressure and PEP/LVET or R-dA/dt/$\sqrt{R\text{-}R}$. Even prior to demonstration of this fact, alterations in after-load were not considered a problem. This was true because bedrest produces no significant or consistent alterations in either resting or exercise blood pressure or peripheral vascular resistance.[4-6]

Having demonstrated that bedrest induced alterations in heart rate, plasma volume (pre-load), and blood pressure (after-load) are not responsible for the prolongations seen in PEP/LVET and R-dA/dt/$\sqrt{R\text{-}R}$, the ultimate conclusion is obvious. The only remaining factor which could influence these measurements is a decrease in the inotrophic state of the myocardium.

CONCLUSION

The present study, utilizing quantitative apexcardiography and measurement of systolic time intervals has demonstrated that bedrest causes a detrimental alteration in the contractile state of the myocardium of healthy volunteers. While these changes have been demonstrated in resting basal subjects, they account for the decreases in maximal oxygen uptake and failure to adequately augment stroke volume and cardiac output during exercise after bedrest. The prolonged nature of this change in inotrophy also accounts for the dichotomy between the rapid return of post-recumbency orthostatic tolerance and the slow return of post-recumbency exercise tolerance.

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TABLES

TABLE 1

COMPOSITE APEX CARDIOGRAPHY DATA

Subject	Week of Study	R-R	R-dA/dt	$\frac{\text{R-dA/dt}}{\sqrt{RR}}$
HT	C 2	.93	.060	.062
	B 4	.80	.070	.078
CT	C 2	1.01	.080	.080
	B 4	.66	.075	.092
GP	C 2	.72	.080	.073
	B 4	.60	.085	.110
RG	C 2	1.21	.080	.073
	B 4	.88	.080	.085
RR	C 2	.92	.125	.130
	B 4	.76	.135	.155
	R 2	.65	.120	.149
	R 3	1.10	.120	.125
DJ	C 2	.94	.105	.108
	B 4	.64	.097	.121
	R 2	.82	.110	.107
	R 3	.78	.095	.108
CC	C 2	.76	.070	.080
	B 4	.81	.075	.083
	R 2	1.11	.077	.073
	R 3	.76	.070	.080
JA	C 2	1.09	.085	.083
	B 4	.86	.103	.111
	R 2	.82	.097	.107
	R 3	1.02	.101	.100
WR	C 2	.94	.100	.102
	B 4	.76	.091	.102
	R 2	.75	.100	.116
	R 3	.83	.080	.087
JW	C 2	.58	.048	.063
	B 4	.61	.085	.104
	R 2	.65	.055	.068
	R 3	.65	.050	.062

TABLE 1

COMPOSITE APEX CARDIOGRAPHY DATA

Subject	Week of Study	R-R	R-dA/dt	$\frac{\text{R-dA/dt}}{\sqrt{RR}}$
JS	C 2	.78	.080	.091
	B 4	.74	.093	.109
	R 2	.73	.096	.112
	R 3	.72	.072	.085
BL	C 2	1.13	.097	.091
	B 1	1.16	.107	.100
	B 2	1.06	.099	.096
	B 4	1.03	.106	.105
	R 2	1.01	.088	.088
	R 3	1.06	.101	.098
RC	C 2	1.07	.100	.099
	B 1	.71	.097	.115
	B 2	.63	.095	.120
	B 4	.81	.120	.133
	R 2	.60	.100	.129
	R 3	.98	.100	.101
DY	C 2	1.20	.106	.096
	B 2	1.23	.136	.123
	B 4	1.05	.121	.118
	R 2	.92	.118	.123
	R 3	.93	.114	.117
RB	C 2	.94	.100	.102
	B 2	1.04	.093	.091
	B 4	1.09	.097	.093
	R 2	.98	.099	.095
RL	C 2	.90	.094	.101
	B 1	1.06	.089	.086
	B 4	.91	.097	.102
	R 2	.68	.093	.113
	R 3	.85	.094	.102
JH	C 2	1.14	.072	.067
	B 2	.98	.109	.110
JV	C 2	.94	.091	.099
	B 2	.74	.106	.123

TABLE 1

COMPOSITE APEX CARDIOGRAPHY DATA

Subject	Week of Study	R-R	R-dA/dt	$\frac{\text{R-dA/dt}}{\sqrt{RR}}$
NR	C 2	.99	.085	.086
	B 1	.95	.120	.123
	B 2	.88	.094	.100
JG	C 2	1.10	.098	.094
	B 1	.91	.124	.130
	B 2	.85	.122	.132
GB	C 2	1.27	.107	.095
	B 1	1.24	.087	.078
	B 2	1.19	.085	.078
GJ	C 2	1.18	.126	.116
	B 2	1.16	.129	.120
RT	C 2	.97	.088	.089
	B 2	.98	.088	.089
RV	C 2	.86	.045	.049
	B 2	.74	.052	.061

TABLE 2

CORRELATION OF R-dA/dt WITH R-R INTERVAL, BLOOD PRESSURE, AND PLASMA VOLUME

(Control Week 2)

Subject	R-dA/dt (sec)	R-R (sec)	Systolic BP (mmHg)	Diastolic BP (mmHg)	Plasma Volume (L)
HT	.060	.93	114	75	2.78
CT	.080	1.01	124	76	3.40
GP	.080	.72	102	74	3.47
RG	.080	1.21	98	58	2.96
RR	.125	.92	106	60	3.61
DJ	.105	.94	110	60	3.12
CC	.070	.76	110	70	2.85
JA	.085	1.09	110	75	2.85
WR	.100	.94	122	70	2.55
JW	.048	.58	110	70	2.85
JS	.080	.78	118	86	2.41
BL	.097	1.13	130	54	3.17
RC	.100	1.07	120	60	3.35
DY	.106	1.20	136	90	3.15
RB	.100	.94	120	72	3.59
RL	.094	.90	112	68	3.07
JH	.072	1.14	110	62	3.94
JV	.091	.94	130	70	3.13
NR	.085	.99	120	68	3.48
JG	.098	1.10	112	72	2.90
GB	.107	1.27	120	80	3.18
GJ	.126	1.18	108	76	2.82
RT	.088	.97	124	82	3.44
RV	.045	.86	130	70	3.33
r		0.525	0.002	-0.033	0.074
P		<0.01	<0.995	<0.9	<0.8

TABLE 3

ALTERATIONS IN QUANTITATIVE APEX CARDIOGRAPHY
INDUCED BY BEDREST

	C 2			B 1		
Subject	R-R	R-dA/dt	$\frac{R\text{-}dA/dt}{\sqrt{RR}}$	R-R	R-dA/dt	$\frac{R\text{-}dA/dt}{\sqrt{RR}}$
BL	1.13	.097	.091	1.16	.107	.100
RC	.90	.096	.101	.71	.097	.115
RL	.90	.094	.101	1.06	.089	.086
NR	.99	.085	.086	.95	.120	.123
JG	1.10	.098	.094	.91	.124	.130
GB	1.27	.107	.095	1.24	.087	.078
Mean	1.05	.096	.095	1.01	.104	.105
SE(95%)	±.15	±.008	±.004	±.21	±.015	±.021
P				<0.50	<0.40	<0.40

TABLE 4

ALTERATIONS IN QUANTITATIVE APEX CARDIOGRAPHY INDUCED BY BEDREST

Subject	C 2			B 2		
	R-R	R-dA/dt	$\frac{\text{R-dA/dt}}{\sqrt{RR}}$	R-R	R-dA/dt	$\frac{\text{R-dA/dt}}{\sqrt{RR}}$
BL	1.13	.097	.091	1.06	.099	.096
RC	.90	.096	.101	.63	.095	.120
DY	1.20	.106	.096	1.23	.136	.123
RB	.94	.100	.102	1.04	.093	.091
JH	1.14	.072	.067	.98	.109	.110
JV	.94	.091	.099	.74	.106	.123
NR	.99	.085	.086	.88	.094	.100
JG	1.10	.098	.094	.85	.122	.132
GB	1.27	.107	.095	1.19	.085	.078
GJ	1.18	.126	.116	1.16	.129	.120
RT	.97	.088	.089	.98	.088	.089
RV	.86	.045	.049	.74	.052	.061
Mean	1.05	.092	.090	.96	.100	.104
SE(95%)	±.08	±.011	±.010	±.13	±.013	±.012
P				<0.02	<0.20	<0.05

TABLE 5

ALTERATIONS IN QUANTITATIVE APEX CARDIOGRAPHY
INDUCED BY BEDREST

	C 2			B 4		
Subject	R-R	R-dA/dt	$\frac{\text{R-dA/dt}}{\sqrt{RR}}$	R-R	R-dA/dt	$\frac{\text{R-dA/dt}}{\sqrt{RR}}$
HT	.93	.060	.062	.80	.070	.078
CT	1.01	.080	.080	.66	.075	.092
GP	.72	.080	.094	.60	.085	.110
RG	1.21	.080	.073	.88	.080	.088
RR	.92	.125	.130	.76	.135	.155
DJ	.94	.105	.108	.64	.097	.121
CC	.76	.070	.080	.81	.075	.083
JA	1.09	.085	.083	.86	.103	.111
WR	.94	.100	.102	.76	.091	.102
JW	.58	.048	.063	.61	.085	.104
JS	.78	.080	.091	.74	.093	.109
BL	1.13	.097	.091	1.03	.106	.105
RC	1.07	.100	.099	.81	.120	.133
DY	1.20	.106	.096	1.05	.121	.118
RB	.94	.100	.102	1.09	.097	.093
RL	.90	.094	.101	.91	.097	.102
Mean	.95	.088	.091	.81	.097	.106
SE(95%)	±.09	±.010	±.009	±.09	±.009	±.010
P				<0.005	<0.05	<0.001

TABLE 6

ALTERATIONS IN QUANTITATIVE APEX CARDIOGRAPHY
INDUCED BY BEDREST

	C 2			R 2		
Subject	R-R	R-dA/dt	$\frac{R\text{-}dA/dt}{\sqrt{RR}}$	R-R	R-dA/dt	$\frac{R\text{-}dA/dt}{\sqrt{RR}}$
RR	.92	.125	.130	.65	.120	.149
DJ	.94	.105	.108	.82	.110	.107
CC	.76	.070	.080	1.11	.077	.073
JA	1.09	.085	.083	.82	.097	.107
WR	.94	.100	.102	.75	.100	.116
JW	.58	.048	.063	.65	.055	.068
JS	.78	.080	.091	.73	.096	.112
BL	1.13	.097	.091	1.01	.088	.088
RC	1.07	.100	.099	.60	.100	.129
DY	1.20	.106	.096	.92	.118	.123
RB	.94	.100	.102	.98	.094	.095
RL	.90	.094	.101	.68	.093	.113
Mean	.94	.093	.096	.81	.096	.107
SE(95%)	±.11	±.013	±.010	±.11	±.011	±.015
P				<0.10	<0.20	<0.02

TABLE 7

ALTERATIONS IN QUANTITATIVE APEX CARDIOGRAPHY
INDUCED BY BEDREST

	C 2			R 3		
Subject	R-R	R-dA/dt	$\frac{R\text{-}dA/dt}{\sqrt{RR}}$	R-R	R-dA/dt	$\frac{R\text{-}dA/dt}{\sqrt{RR}}$
RR	.92	.125	.130	1.10	.120	.125
DJ	.94	.105	.108	.78	.095	.108
CC	.76	.070	.080	.76	.070	.080
JA	1.09	.085	.083	1.02	.101	.100
WR	.94	.100	.102	.83	.080	.087
JW	.58	.048	.063	.65	.050	.062
JS	.78	.080	.091	.72	.072	.085
BL	1.13	.097	.091	1.06	.101	.098
RC	1.07	.100	.099	.98	.100	.101
DY	1.20	.106	.096	.93	.114	.117
RL	.90	.094	.101	.85	.094	.102
Mean	.94	.092	.095	.88	.091	.097
SE(95%)	±.11	±.013	±.012	±.09	±.013	±.010
P				<0.20	<0.40	<0.60

TABLE 8

ALTERATIONS IN $\frac{\text{R-dA/dt}}{\sqrt{RR}}$ INDUCED BY BEDREST

Control $\frac{\text{R-dA/dt}}{\sqrt{RR}}$	Week of Study	Bedrest & Recovery $\frac{\text{R-dA/dt}}{\sqrt{RR}}$	P	Subjects Showing Prolongation
.095 ±.004	B1	.105 ±.021	<0.40	4/6 (67%)
.090 ±.010	B2	.104 ±.012	<0.05	10/13 (77%)
.091 ±.009	B4	.106 ±.010	<0.001	14/16 (88%)
.096 ±.010	R2	.107 ±.015	<0.02	8/12 (67%)
.095 ±.012	R3	.097 ±.010	<0.60	5/11 (45%)

TABLE 9

ALTERATIONS IN R-dA/dt INDUCED BY BEDREST
(Predicted* vs Experimental)

	C2		B1		B2		B4		R2		R3	
Subject	Pred.	Exp.	Pred.	Exp.	Pred.	Exp.	Pred.	Exp.	Pred.	Exp.	Pred.	Exp.
HT	.085	.060					.077	.070				
CT	.090	.080					.068	.075				
GP	.072	.080					.064	.085				
RG	.103	.080					.082	.080				
RR	.084	.125					.074	.135	.067	.120	.096	.120
DJ	.086	.105					.067	.097	.078	.110	.076	.095
CC	.074	.070					.078	.075	.096	.007	.074	.070
JA	.095	.085					.081	.103	.078	.097	.091	.101
WR	.086	.100					.074	.091	.074	.100	.079	.080
JW	.063	.048					.065	.085	.067	.055	.067	.050
JS	.076	.080					.073	.093	.073	.096	.072	.072
BL	.098	.097	.093	.089	.093	.099	.091	.106	.090	.088	.093	.101
RC	.094	.100	.071	.097	.066	.095	.078	.120	.064	.100	.088	.100
DY	.102	.106			.104	.136	.093	.121	.084	.118	.085	.114
RB	.086	.100			.092	.093	.095	.097	.088	.094		
RL	.083	.094	.093	.089			.084	.097	.069	.093	.080	.094
JH	.098	.072			.088	.109						
JV	.086	.091			.073	.106						
NR	.089	.085	.086	.120	.082	.094						
JG	.096	.098	.086	.124	.080	.122						
GB	.106	.107	.105	.087	.101	.085						
GJ	.101	.126			.099	.129						
RT	.088	.088			.088	.088						
RV	.081	.045			.073	.052						
Mean	.088	.088	.089	.101	.087	.100	.078	.097	.077	.096	.082	.091
SE(95%)	±.004	±.007	±.012	±.018	±.008	±.013		±.009	±.007	±.011	±.006	±.013
P		<0.999		<0.3		<0.05		<0.001		<0.02		<0.05

*Prediction Equation: R-dA/dt = 0.0629 R-R + 0.0266

TABLE 10

PLASMA VOLUME ALTERATIONS

Apex Cardiography Group

Subject	Plasma Volume (L)	
	Control	B 1
BL	3.17	3.02
RC	3.35	3.34[2]
RL[1]	3.07	
NR	3.48	3.47
JG	2.90	2.72
GB[1]	3.18	
Mean	3.23	3.14
SE(95%)	±.40	±.53
P		<.20

[1]Not used in calculations.

[2]Receiving 9-alpha-fluorohydrocortisone.

TABLE 11

PLASMA VOLUME ALTERATIONS

Apex Cardiography Group

Subject	Plasma Volume (L)	
	Control	B 2
BL[1]	3.17	
RC[1]	3.35	—[2]
DY	3.15	2.81
RB	3.59	3.13
JH	3.94	3.52
JV[1]	3.13	
NR	3.48	3.28
JG	2.90	2.60
GB	3.18	3.25
GJ	2.82	2.68
RT	3.44	3.03
RV	3.33	2.67
Mean	3.32	3.00
SE(95%)	±.27	±.25
P		<0.005

[1]Data not used in calculations.

[2]Receiving 9-alpha-fluorohydrocortisone.

TABLE 12

PLASMA VOLUME ALTERATIONS

Apex Cardiography Group

Subject	Plasma Volume (L)	
	Control	B 4
HT	2.78	2.70
CT	3.40	3.14
GP	3.47	2.93
RG	2.96	2.91
RR	3.61	3.04
DJ[1]	3.12	
CC	2.85	2.88
JA	2.85	2.49
WR[1]	2.55	_[2]
JW	2.85	2.69[2]
JS	2.41	2.90[2]
BL	3.17	3.00
RC	3.35	3.39[2]
DY	3.15	2.70
RB	3.59	3.22
RL	3.07	2.89[2]
Mean	3.11	2.92
SE(95%)	±.20	±.14
P		<0.05

[1]Not used in calculations.

[2]Receiving 9-alpha-fluorohydrocortisone.

TABLE 13

PLASMA VOLUME ALTERATIONS

Apex Cardiography Group

Subject	Plasma Volume (L)	
	Control	R 2
RR	3.61	3.43
DJ	3.12	3.19
CC	2.85	3.56
JA	2.85	2.91
WR	2.55	2.45
JW	2.85	3.07
JS	2.41	2.98
BL	3.17	3.40
RC	3.35	3.62
DY	3.15	3.40
RB	3.59	3.36
RL	3.07	3.26
Mean	3.05	3.22
SE(95%)	±.23	±.21
P		<0.10

TABLE 14

PLASMA VOLUME - APEX CARDIOGRAPHY GROUP

(Liters - Mean ±SE 95%)

Control Plasma Volume	Week of Study	Bedrest & Recovery Plasma Volume	P
3.23 ±.40	B1	3.14 ±.53	<0.20
3.32 ±.27	B2	3.00 ±.25	<.005
3.11 ±.20	B4	2.92 ±.14	<.05
3.05 ±.23	R2	3.22 ±.21	<.10

TABLE 15

CORRELATION BETWEEN $\frac{R\text{-}dA/dt}{\sqrt{R\text{-}R}}$ AND PLASMA VOLUME ALTERATIONS

	Bedrest Week 1	
Subject	$\Delta \frac{R\text{-}dA/dt}{\sqrt{R\text{-}R}}$	Δ Plasma Volume
BL	.009	-.15
RC	.014	-.01
RL[1]	-.015	
NR	.027	-.01
JG	.036	-.18
GB[1]	-.017	
r		-0.22
P		<0.80

[1]Data not used in calculations.

TABLE 16

CORRELATION BETWEEN $\frac{R\text{-}dA/dt}{\sqrt{R\text{-}R}}$ AND PLASMA VOLUME ALTERATIONS

	Bedrest Week 2	
Subject	$\Delta \frac{R\text{-}dA/dt}{\sqrt{R\text{-}R}}$	Δ Plasma Volume
BL[1]	.005	
RC[1]	.019	
DY	.027	-.34
RB	-.011	-.46
JH	.043	-.42
JV[1]	.024	
NR	.014	-.20
JG	.038	-.30
GB	-.017	.07
GJ	.004	-.14
RT	.000	-.41
RV	.012	-.66
r		-0.32
P		<0.40

[1]Data not used in calculations.

TABLE 17

CORRELATION BETWEEN $\frac{R\text{-}dA/dt}{\sqrt{R\text{-}R}}$ AND PLASMA VOLUME ALTERATIONS

Bedrest Week 4

Subject	$\Delta \frac{R\text{-}dA/dt}{\sqrt{R\text{-}R}}$	Δ Plasma Volume
HT	.016	-.08
CT	.012	-.26
GP	.016	-.54
RC	.015	-.05
RR	.025	-.55
DJ[1]	.015	
CC	.003	.03
JA	.028	-.36
WR[1]	.000	
JW	.041	-.16
JS	.018	.49
BL	.014	-.17
RC	.034	-.04
DY	.022	-.45
RB	-.009	-.37
RL	-.001	-.18
r		-0.01
P		<0.98

[1]Data not used in calculations.

TABLE 18

CORRELATION BETWEEN $\frac{R\text{-}dA/dt}{\sqrt{R\text{-}R}}$ AND PLASMA VOLUME ALTERATIONS

	Recovery Week 2	
Subject	$\Delta \frac{R\text{-}dA/dt}{\sqrt{R\text{-}R}}$	Δ Plasma Volume
RR	.019	-.18
DJ	-.001	.05
CC	-.007	.71
JA	.024	.06
WR	.014	-.10
JW	.005	.22
JS	.021	.57
BL	-.003	.23
RC	.030	.27
DY	.027	.25
RB	-.007	-.23
RL	.012	.19
r		-0.001
P		<0.99

TABLE 19

COMPOSITE SYSTOLIC TIME INTERVAL DATA

Subject	Week of Study	R-R	Q-S_2	Q-S_2I	LVET	LVETI	PEP	PEPI	$\frac{PEP}{LVET}$
CC	C 2	.83	.370	.521	.282	.405	.089	.118	.317
	B 4	.85	.394	.541	.292	.412	.102	.130	.350
	R 2	1.00	.431	.557	.326	.428	.105	.129	.322
	R 3	.81	.386	.541	.289	.414	.097	.122	.336
JA	C 2	1.15	.463	.572	.342	.431	.121	.142	.354
	B 4	.96	.430	.562	.310	.416	.120	.145	.387
	R 2	.85	.427	.575	.306	.426	.121	.149	.395
	R 3	1.01	.442	.566	.320	.422	.122	.146	.381
JS	C 2	.79	.355	.515	.275	.403	.080	.110	.291
	B 4	.79	.382	.542	.289	.417	.097	.127	.336
	R 2	.76	.372	.538	.285	.419	.087	.119	.305
	R 3	.69	.372	.555	.285	.432	.087	.122	.305
BL	C 2	1.13	.379	.490	.302	.392	.077	.098	.255
	B 1	1.16	.395	.507	.314	.402	.084	.105	.268
	B 2	1.06	.373	.491	.297	.393	.076	.099	.256
	B 4	1.08	.374	.490	.292	.386	.082	.104	.281
	R 2	1.01	.373	.499	.302	.404	.071	.095	.235
	R 3	1.06	.384	.502	.305	.401	.079	.101	.259
RC'	C 2	.88	.385	.528	.290	.406	.094	.121	.324
	B 1	.73	.351	.523	.258	.402	.093	.126	.360
	B 2	.61	.309	.515	.228	.395	.081	.120	.355
DY	C 2	1.20	.409	.514	.325	.410	.084	.104	.259
	B 2	1.23	.425	.548	.318	.401	.107	.127	.336
	B 4	1.05	.409	.529	.306	.404	.103	.126	.337
	R 2	.95	.411	.543	.300	.408	.111	.136	.370
RB	C 2	.93	.420	.554	.298	.407	.123	.149	.412
	B 2	1.04	.424	.545	.299	.395	.125	.148	.418
	B 4	1.09	.437	.552	.313	.406	.124	.146	.396
	R 2	.98	.438	.567	.306	.411	.132	.157	.431
RL	C 2	.90	.381	.522	.293	.407	.088	.115	.300
	B 1	1.06	.413	.531	.305	.401	.108	.131	.354
	B 4	.93	.403	.537	.297	.409	.106	.135	.357
	R 2	.68	.374	.561	.275	.421	.099	.135	.360
	R 3	.85	.392	.540	.289	.409	.103	.131	.356
JH	C 2	1.38	.463	.553	.346	.420	.117	.134	.338
	B 2	1.08	.433	.551	.325	.420	.108	.130	.332

TABLE 19

COMPOSITE SYSTOLIC TIME INTERVAL DATA

Subject	Week of Study	R-R	Q-S_2	Q-S_2I	LVET	LVETI	PEP	PEPI	$\frac{PEP}{LVET}$
JV	C 2	.89	.387	.528	.288	.402	.099	.126	.344
	B 1	.76	.348	.514	.248	.382	.100	.132	.403
	B 2	.88	.373	.517	.272	.410	.101	.128	.371
	B 4	.64	.320	.516	.238	.396	.082	.119	.345
NR	C 2	.99	.403	.530	.308	.411	.095	.119	.308
	B 1	.98	.391	.519	.283	.390	.108	.133	.381
	B 2	.88	.372	.515	.279	.395	.093	.120	.333
JG	C 2	1.10	.411	.526	.322	.415	.089	.111	.279
	B 1	.92	.356	.493	.269	.381	.087	.113	.323
	B 2	.85	.362	.510	.263	.383	.099	.127	.376
GB	C 2	1.27	.445	.543	.327	.407	.118	.137	.360
	B 1	1.24	.426	.526	.310	.393	.116	.135	.374
	B 2	1.19	.436	.542	.301	.387	.135	.155	.449
JP	C 2	1.28	.421	.519	.320	.400	.101	.120	.316
	B 1	1.41	.436	.524	.329	.401	.107	.124	.325
	B 2	1.53	.449	.531	.343	.410	.106	.122	.309
JB	C 2	.86	.412	.559	.303	.421	.109	.137	.360
	B 4	.74	.385	.556	.275	.413	.110	.142	.400
	R 2	.77	.401	.567	.280	.413	.121	.152	.401
	R 3	.83	.432	.584	.304	.427	.128	.157	.421
GJ	C 2	1.18	.444	.551	.324	.411	.120	.140	.369
	B 2	1.16	.415	.524	.325	.413	.090	.111	.277
	B 4	.97	.388	.519	.287	.393	.101	.126	.352
	R 2	1.08	.423	.539	.315	.409	.108	.130	.343
RT	C 2	.86	.409	.556	.307	.426	.103	.131	.335
	B 2	.97	.417	.547	.308	.412	.109	.134	.354
RV	C 2	.89	.389	.520	.287	.401	.102	.129	.356
	B 2	.74	.368	.537	.266	.403	.102	.134	.386
LC	C 2	.91	.372	.510	.287	.399	.085	.111	.296
	B 2	1.01	.387	.513	.280	.387	.107	.131	.382
AM	C 2	1.26	.432	.532	.322	.404	.110	.129	.343
	B 2	1.16	.418	.526	.326	.413	.092	.113	.282

TABLE 20

CORRELATION OF PEP/LVET WITH R-R INTERVAL, BLOOD PRESSURE, AND PLASMA VOLUME

(Control Week 2)

Subject	PEP/LVET	R-R (sec)	Systolic BP (mmHg)	Diastolic BP (mmHg)	Plasma Volume (L)
CC	.317	.83	110	70	2.85
JA	.354	1.15	110	75	2.85
JS	.291	.79	118	86	2.41
BL	.255	1.13	130	54	3.17
RC'	.324	.88	110	60	4.03
DY	.259	1.20	136	90	3.15
RB	.412	.93	120	72	3.59
RL	.300	.90	112	68	3.07
JH	.338	1.38	110	62	3.94
JV	.344	.89	130	70	3.13
NR	.308	.99	120	68	3.48
JG	.279	1.10	112	72	2.90
GB	.360	1.27	120	80	3.18
JP	.316	1.28	116	78	3.65
JB	.360	.86	115	75	3.27
GJ	.369	1.18	108	76	2.82
RT	.335	.86	124	82	3.44
RV	.356	.89	130	70	3.33
LC	.296	.91	124	84	2.71
AM	.343	1.26	114	74	2.82
r		-0.019	-0.290	-0.012	0.239
P		<0.95	<0.3	<0.975	<0.4

TABLE 21

ALTERATIONS IN SYSTOLIC TIME INTERVALS INDUCED BY BEDREST

	C 2					B 1				
Subject	R-R	$Q\text{-}S_2I$	LVETI	PEPI	$\frac{PEP}{LVET}$	R-R	$Q\text{-}S_2I$	LVETI	PEPI	$\frac{PEP}{LVET}$
BL	1.13	.490	.392	.098	.255	1.16	.507	.402	.105	.268
RC'	.88	.528	.406	.121	.324	.73	.523	.402	.126	.360
RL	.90	.522	.407	.115	.300	1.06	.531	.401	.131	.354
JV	.89	.528	.402	.126	.344	.76	.514	.382	.132	.403
NR	.99	.530	.411	.119	.308	.98	.519	.390	.133	.381
JG	1.10	.526	.415	.111	.279	.92	.493	.381	.113	.323
GB	1.27	.543	.407	.137	.360	1.24	.526	.393	.135	.374
JP	1.28	.519	.400	.120	.316	1.41	.526	.401	.124	.325
Mean	1.06	.523	.405	.119	.311	1.03	.517	.394	.125	.349
SE(95%)	±.14	±.012	±.005	±.009	±.028	±.19	±.009	±.007	±.009	±.035
P						<0.70	<0.40	<0.05	<0.01	<0.0025

TABLE 22

ALTERATIONS IN SYSTOLIC TIME INTERVALS INDUCED BY BEDREST

	C 2					B 2				
Subject	R-R	Q-S_2I	LVETI	PEPI	$\frac{PEP}{LVET}$	R-R	Q-S_2I	LVETI	PEPI	$\frac{PEP}{LVET}$
BL	1.13	.490	.392	.098	.255	1.06	.491	.393	.099	.256
RC'	.88	.528	.406	.124	.327	.61	.515	.395	.120	.355
DY	1.20	.514	.410	.104	.259	1.23	.548	.401	.127	.336
RB	.94	.554	.404	.149	.412	1.04	.545	.395	.148	.418
JH	1.38	.553	.420	.134	.338	1.08	.551	.420	.130	.332
JV	.89	.529	.402	.126	.344	.88	.517	.410	.128	.371
NR	.99	.530	.411	.119	.308	.88	.515	.395	.120	.333
JG	1.10	.526	.415	.111	.279	.85	.510	.383	.127	.376
GB	1.27	.543	.407	.137	.360	1.19	.542	.387	.155	.449
JP	1.28	.519	.400	.120	.316	1.53	.531	.410	.122	.309
GJ	1.18	.551	.411	.140	.369	1.16	.524	.413	.111	.277
RT	.86	.556	.426	.131	.335	.97	.547	.412	.134	.354
RV	.89	.520	.401	.129	.356	.74	.537	.403	.134	.386
LC	.91	.510	.399	.111	.296	1.01	.513	.387	.131	.382
AM	1.26	.532	.404	.129	.343	1.16	.526	.413	.113	.282
Mean	1.07	.530	.407	.124	.326	1.03	.527	.401	.127	.348
SE(95%)	±.10	±.011	±.004	±.006	±.024	±.12	±.007	±.006	±.006	±.030
P						<.15	<.20	<.10	<.25	<.10

TABLE 23

ALTERATIONS IN SYSTOLIC TIME INTERVALS INDUCED BY BEDREST

	C 2					B 4				
Subject	R-R	Q-S_2I	LVETI	PEPI	$\frac{PEP}{LVET}$	R-R	Q-S_2I	LVETI	PEPI	$\frac{PEP}{LVET}$
CC	.83	.521	.405	.118	.317	.85	.541	.412	.130	.350
JA	1.15	.572	.431	.142	.354	.96	.562	.416	.145	.387
JS	.79	.515	.403	.110	.291	.79	.542	.417	.127	.336
BL	1.13	.490	.392	.098	.255	1.08	.490	.386	.104	.281
DY	1.20	.514	.410	.104	.259	1.05	.529	.404	.126	.337
RB	.93	.554	.407	.149	.413	1.09	.552	.406	.146	.396
RL	.90	.522	.407	.115	.300	.93	.537	.409	.135	.357
JV	.89	.528	.402	.126	.344	.64	.516	.396	.119	.345
JB	.86	.559	.421	.137	.360	.74	.556	.413	.142	.400
GJ	1.18	.551	.411	.410	.369	.97	.519	.393	.126	.352
Mean	.99	.533	.409	.124	.326	.91	.534	.405	.130	.354
SE(95%)	±.11	±.018	±.007	±.012	±.036	±.11	±.015	±.007	±.009	±.025
P						<0.10	<0.80	<0.20	<0.20	<0.02

TABLE 24

ALTERATIONS IN SYSTOLIC TIME INTERVALS INDUCED BY BEDREST

	C 2					R 2				
Subject	R-R	Q-S_2I	LVETI	PEPI	$\frac{PEP}{LVET}$	R-R	Q-S_2I	LVETI	PEPI	$\frac{PEP}{LVET}$
CC	.83	.521	.405	.118	.317	1.00	.557	.428	.129	.322
JA	1.15	.572	.431	.142	.354	.85	.575	.426	.149	.395
JS	.79	.515	.403	.110	.291	.76	.538	.419	.119	.305
BL	1.13	.490	.392	.098	.255	1.01	.499	.404	.095	.235
DY	1.20	.514	.410	.104	.259	.95	.543	.408	.136	.370
RB	.93	.554	.407	.149	.412	.98	.567	.411	.157	.431
RL	.90	.522	.407	.115	.300	.68	.561	.421	.135	.360
JB	.86	.559	.421	.137	.360	.77	.567	.413	.152	.401
GJ	1.18	.551	.411	.140	.369	1.08	.539	.409	.130	.343
Mean	1.00	.533	.410	.123	.324	.90	.550	.415	.134	.351
SE(95%)	±.13	±.026	±.008	±.014	±.041	±.11	±.018	±.006	±.014	±.045
P						<0.10	<0.02	<0.20	<.005	<0.10

TABLE 25

ALTERATIONS IN SYSTOLIC TIME INTERVALS INDUCED BY BEDREST

	C 2					R 3				
Subject	R-R	Q-S_2I	LVETI	PEPI	$\frac{PEP}{LVET}$	R-R	Q-S_2I	LVETI	PEPI	$\frac{PEP}{LVET}$
CC	.83	.521	.405	.118	.317	.81	.541	.414	.122	.336
JA	1.15	.572	.431	.142	.354	1.01	.566	.422	.146	.381
JS	.79	.515	.403	.110	.291	.69	.555	.432	.122	.305
BL	1.13	.490	.392	.098	.255	1.06	.502	.401	.101	.259
RL	.90	.522	.407	.115	.300	.85	.540	.409	.131	.356
JB	.86	.559	.421	.137	.360	.83	.584	.427	.157	.421
Mean	.94	.530	.410	.120	.313	.88	.548	.418	.130	.343
SE(95%)	±.15	±.031	±.015	±.017	±.041	±.14	±.028	±.012	±.020	±.059
P						<0.02	<0.0125	<0.20	<0.02	<0.025

TABLE 26

ALTERATIONS IN PEP/LVET
INDUCED BY BEDREST

Control PEP/LVET	Week of Study	Bedrest & Recovery PEP/LVET	P	Subjects Showing Increase	
.311 ±.028	B1	.349 ±.035	<0.0025	8/8	(100%)
.326 ±.024	B2	.348 ±.030	<0.10	11/15	(73%)
.326 ±.036	B4	.354 ±.025	<0.02	9/10	(90%)
.324 ±.041	R2	.351 ±.045	<0.10	7/9	(78%)
.313 ±.041	R3	.343 ±.059	<0.025	6/6	(100%)

TABLE 27

PLASMA VOLUME ALTERATIONS

STI Group

Subject	Plasma Volume (L)	
	Control	B 1
BL	3.17	3.02
RC'	4.03	4.02
RL[1]	3.07	
JV	3.13	3.06
NR	3.48	3.47
JG	2.90	2.72
GB[1]	3.18	
JP	3.65	3.31
Mean	3.39	3.27
SE(95%)	±.43	±.47
P		<0.10

[1]Not used in calculations.

TABLE 28

PLASMA VOLUME ALTERATIONS

STI Group

Subject	Plasma Volume (L)	
	Control	B 2
BL[1]	3.17	
RC'[1]	4.03	
DY	3.15	2.81
RB	3.59	3.13
JH	3.94	3.52
JV[1]	3.13	
NR	3.48	3.28
JG	2.90	2.60
GB	3.18	3.25
JP	3.65	3.47
GJ	2.82	2.68
RT	3.44	3.03
RV	3.33	2.67
LC	2.71	2.62
AM	2.82	2.70
Mean	3.25	2.98
SE(95%)	±.25	±.22
P		<0.001

[1]Not used in calculations.

TABLE 29

PLASMA VOLUME ALTERATIONS

STI Group

Subject	Plasma Volume (L)	
	Control	B 4
CC	2.85	2.88
JA	2.85	2.49
JS	2.41	2.90[1]
BL	3.17	3.00
DY	3.15	2.70
RB	3.59	3.22
RL	3.07	2.89[1]
JV	3.13	3.15
JB	3.27	3.27[1]
GJ	2.82	2.64
Mean	3.03	2.91
SE(95%)	±.23	±.18
P		<0.20

[1]Receiving 9-alpha-fluorohydrocortisone.

TABLE 30

PLASMA VOLUME ALTERATIONS

STI Group

	Plasma Volume (L)	
Subject	Control	R 2
CC	2.85	3.56
JA	2.85	2.91
JS	2.41	2.98
BL	3.17	3.40
DY	3.15	3.40
RB	3.59	3.36
RL	3.07	3.26
JB	3.27	3.15
GJ	2.82	2.72
Mean	3.02	3.19
SE(95%)	±.26	±.21
P		<0.20

TABLE 31

PLASMA VOLUME - STI GROUP

(Liters - Mean ±SE 95%)

Control Plasma Volume	Week of Study	Bedrest & Recovery Plasma Volume	P
3.39 ±.43	B1	3.27 ±.47	<0.10
3.25 ±.25	B2	2.98 ±.22	<.0001
3.03 ±.23	B4	2.91 ±.18	<.20
3.02 ±.26	R2	3.19 ±.21	<.20

TABLE 32

CORRELATION BETWEEN PEP/LVET AND PLASMA VOLUME ALTERATIONS

	Bedrest Week 1	
Subject	Δ PEP/LVET	Δ Plasma Volume
BL	.013	-.15
RC'	-.036	-.01
RL[1]	.054	
JV	.059	-.07
NR	.073	-.01
JG	.044	-.18
GB[1]	.014	
JP	.009	-.34
r		0.12
P		<0.90

[1]Data not used in calculations.

TABLE 33

CORRELATION BETWEEN PEP/LVET AND PLASMA VOLUME ALTERATIONS

	Bedrest Week 2	
Subject	Δ PEP/LVET	Δ Plasma Volume
BL[1]	.001	
RC'[1]	.028	
DY	.077	-.34
RB	.006	-.46
JH	-.006	-.42
JV[1]	.027	
NR	.025	-.20
JG	.097	-.30
GB	.089	.07
JP	-.007	-.18
GJ	-.092	-.14
RT	.019	-.41
RV	.030	-.66
JV	.086	-.09
AM	-.060	-.12
r		0.02
P		<0.95

[1]Data not used in calculations.

TABLE 34

CORRELATION BETWEEN PEP/LVET AND PLASMA VOLUME ALTERATIONS

	Bedrest Week 4	
Subject	Δ PEP/LVET	Δ Plasma Volume
CC	.033	.03
JA	.033	-.36
JS	.045	.49
BL	.026	-.17
DY	.078	-.45
RB	-.017	-.37
RL	.057	-.18
JV	.001	-.02
JB	-.040	.00
GJ	-.017	-.18
r		-0.06
P		<0.90

TABLE 35

CORRELATION BETWEEN PEP/LVET AND PLASMA VOLUME ALTERATIONS

	Recovery Week 2	
Subject	Δ PEP/LVET	Δ Plasma Volume
CC	.005	.71
JA	.041	.06
JS	.014	.57
BL	-.020	.23
DY	.011	.25
RB	.019	-.23
RL	.060	.19
JB	.041	-.12
GJ	-.026	-.10
r		-0.12
P		<0.80

TABLE 36

ECHOCARDIOGRAPHY

General Data - Cardiac Catheterization Group

Subject	Age	Diagnosis
MM	47	Mitral stenosis, mild aortic regurgitation.
EC	64	Moderate mitral stenosis and severe mitral regurgitation.
CN	46	Severe cardiomyopathy.
CM	52	Moderate aortic regurgitation.
EK	31	Moderate mitral regurgitation.
JG	20	Asymptomatic murmur.
AM	44	Severe mitral stenosis, aortic regurgitation.
CR	56	Coronary artery disease.
DH	55	Severe mitral stenosis.
EW	68	? I.H.S.S., cardiomyopathy.
DJ	46	Coronary artery disease.
HM	46	After aneurysm removal.
JA	68	Severe mitral regurgitation, tricuspid regurgitation.
FV	29	Moderate mitral regurgitation.
JS	43	Coronary artery disease.
AC	26	Severe mitral stenosis.
LK	67	Radiation peri-myocarditis.
FC	47	Coronary artery disease.
HV	60	Coronary artery disease.
RL	48	Mild mitral regurgitation, ? cardiomyopathy.
BH	62	Cardiomyopathy.
Mean	48.8	

TABLE 37

Cardiac Catheterization Group

Values of Echocardiographic Parameters and Intravascularly Obtained Indices of Left Ventricular Function

Subject	Heart Rate	PWV cm/sec	PWE cm	PWV x PWE cm^2/sec	Maximum LV dP/dt	PCV mmHg	LVEDP mmHg	EDV ml	EF %	Fick C.O. L/min
MM	70	3.23	0.93	3.02	1160	17	12	191	77	4.32
EC	80	2.71	0.81	2.19	1850	20	24	172	68	3.40
CN	84	1.41	0.45	0.64	1080	11	20	405	19	2.70
CM	68	2.50	0.60	1.50		16	22	328	67	7.60
EK	90	2.06	0.44	0.91	1750	18	20	322	76	6.80
JG	74	2.77	0.62	1.72		11		163	86	8.87
AM	81	2.07	0.39	0.81	1400	25	16	3.4	27	3.49
CR	62	3.03	0.82	2.48	1260	11	10	105	62	5.85
DH	92	1.49	0.27	0.40	1810	11	12	111		3.90
EW	54	1.93	0.57	1.10		10	18	345	25	3.18
DJ	86	2.58	0.64	1.66	1720	10	9	141	76	5.93
HM	84	2.57	0.74	1.90	2260	7	7	224	60	5.61
JA	96	4.34	1.58	6.84	1650	18	13	205	81	4.03
FV	72	2.71	0.70	1.89	2080	10	8	158	81	3.85
JS	80	2.21	0.60	1.63	2750	8	6	146	70	4.86
AC	94	2.29	0.62	1.40	2640	25	5	94		4.12
LK	98	1.95	0.58	1.12	2950	20	22	114	45	4.50
FC	75	2.33	0.54	1.20	1410	16	16	277	24	5.66
HV	80	1.63	0.21	1.43		10		235	47	5.78
RL	118	1.84	0.17	1.34	1350	33	45	229	16	2.19
BH	74	0.94	0.27	1.23	1560	28	20	268	19	2.49
Mean	81.5	2.31	0.60	1.59	1704	16	16	217	60	4.53

TABLE 37

Cardiac Catheterization Group

Values of Echocardiographic Parameters and Intravascularly Obtained Indices of Left Ventricular Function

Subject	Angio C.O. L/min	Fick C.I. L/mm/BSA	S.V. Fick ml	S.V. Angio ml	V_{max} Circum/sec	LVET sec	ICT sec	Tension Time Index	R-dP/dt sec
MM	7.26	2.66	64	165	1.78	0.380	0.095	21	0.124
EC	9.30	2.00	42	117	1.99	0.320	0.065	23	0.096
CN	6.80	1.50	24	76	1.20	0.260	0.160	15	0.170
CM	14.60	3.50	115	221		0.280	0.070	18	0.102
EK	16.50	3.80	87	251	1.65	0.285	0.065	16	0.142
JG	9.30	4.62	110	140					
AM	7.05	2.42	55	87	1.37	0.250	0.180	34	0.126
CR	10.20	3.05	100	171	1.58	0.315	0.120	18	0.136
DH	7.74	2.30	49	90	1.38	0.290	0.120	19	0.124
EW	5.26	1.98	66	86		0.330	0.120	6	
DJ		3.43		107	1.23	0.295	0.080	10	0.120
HM		3.05	66	135	1.93	0.320	0.100	16	0.118
JA		2.40	45	168	1.31	0.270	0.096	11	0.116
FV		2.25	56	128	1.61	0.280	0.110	15	0.140
JS		2.66	73	130	1.63	0.310	0.095	23	0.112
AC	7.32	2.78	87	77	2.34	0.320	0.090	21	0.108
LK	8.90	2.52	47	89	1.95	0.270	0.095	24	0.112
FC		3.14	80	69	1.20	0.280	0.130	17	0.130
HV	9.60	3.32	73	128					
RL		1.39	18	36	1.34	0.210	0.140	12	0.114
BH		1.34	26	52	1.23	0.230	0.100	15	0.124
Mean	6.42	2.67	64	120	1.48	0.290	0.107	17.6	0.123

TABLE 38

Cardiac Catheterization Group

Echocardiographic Parameters - Summarized Correlation Coefficients and Significance Levels

	PWV		PWE		PWV x PWE	
	r	P	r	P	r	P
Max LV dP/dt	-.05	NS	.02	NS	.06	NS
PCV	-.12	NS	.20	NS	-.14	NS
LVEDP	-.26	NS	-.41	<.10	-.30	NS
EDV	-.32	NS	-.24	NS	-.22	NS
EF	.74	<.001	.65	<.05	.61	<.05
Fick C.O.	.30	NS	-.10	NS		NS
Angio C.O.	.16	NS		NS		NS
Fick C.I.	.34	NS	.13	NS	.14	NS
S.V. Fick	.32	NS	.14	NS		NS
S.V. Angio	-.24	NS	.42	<.05	.40	<.10
V_{max}	.19	NS	.19	NS	-.02	NS
LVET	.43	<.10	.49	<.05	.20	NS
ICT	-.31	NS	-.46	<.05	-.31	NS
Tension Time Index	-.07	NS	-.13	NS		NS
R-dP/dt	-.25	NS	-.26	NS	.44	<.1

TABLE 39

Cardiac Catheterization Group

Echocardiographic Parameters: Correlations With Ejection Fraction in Patients With and Without Coronary Artery Disease

		PWV cm/sec	PWE cm	PWV x PWE cm^2/sec
Patients Without Coronary Disease n = 14	r	.83	.73	.62
	P	<.001	<.001	<.01
Patients With Coronary Disease n = 5	r	.32	.41	.53
	P	NS	NS	NS

TABLE 40

ECHOCARDIOGRAPHY - BEDREST GROUP

Posterior Wall Velocity
(cm/sec)

Subject	Week of Study					
	C1	C2	B2	B4	R1	R2
RC	1.29			1.86		1.57
DY		2.76	2.95		2.74	
RB	3.55	2.45	3.45	1.90	1.33	2.33
JV	1.74			2.26		2.65
GB	2.42	2.34	3.22	2.06		2.68
JP	1.99	2.23	3.24		3.07	2.66
GJ	1.22	4.30	1.85	2.10	2.66	1.70
RT		2.15	4.40	3.54	2.88	1.72
LC	3.21	2.94	3.18	4.38	2.37	3.67
AM	3.32	2.29	2.95	3.42	2.61	

TABLE 41

ECHOCARDIOGRAPHY - BEDREST GROUP

Posterior Wall Excursion
(cm)

Subject	Week of Study					
	C1	C2	B2	B4	R1	R2
RC	.39			.55		.37
DY		.61	.64		.56	
RB	.89	.63	.75	.44	.31	.45
JV	.51			.65		.47
GB	.56	.54	.83		.53	.55
JP	.47	.54	.74		.67	.53
GJ	.41	1.40	.50	.63	.78	.47
RT		.51	1.23	.72	.68	.47
LC	.76	.54	.55	.86	.46	.83
AM	.99	.49	.77	.92	.73	

FIGURES

FIGURE 1

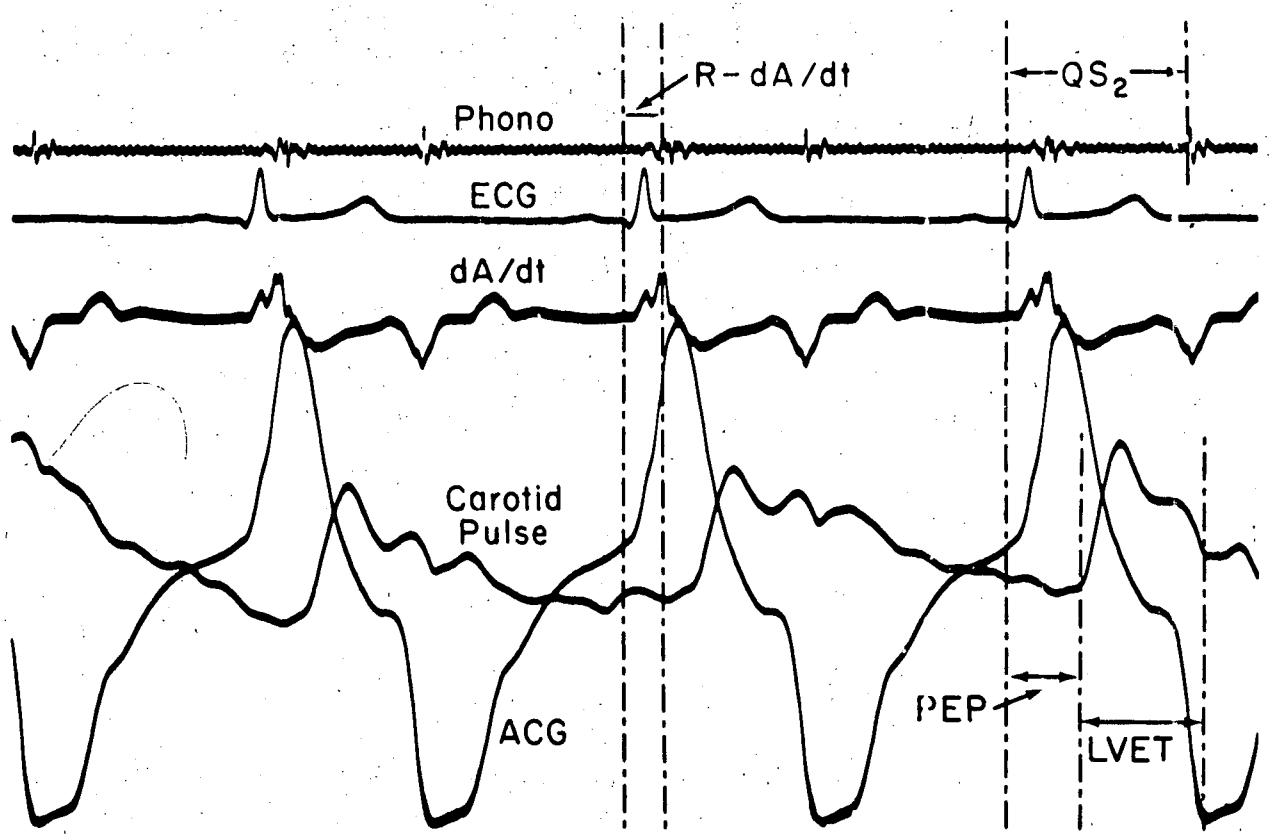


FIGURE 2

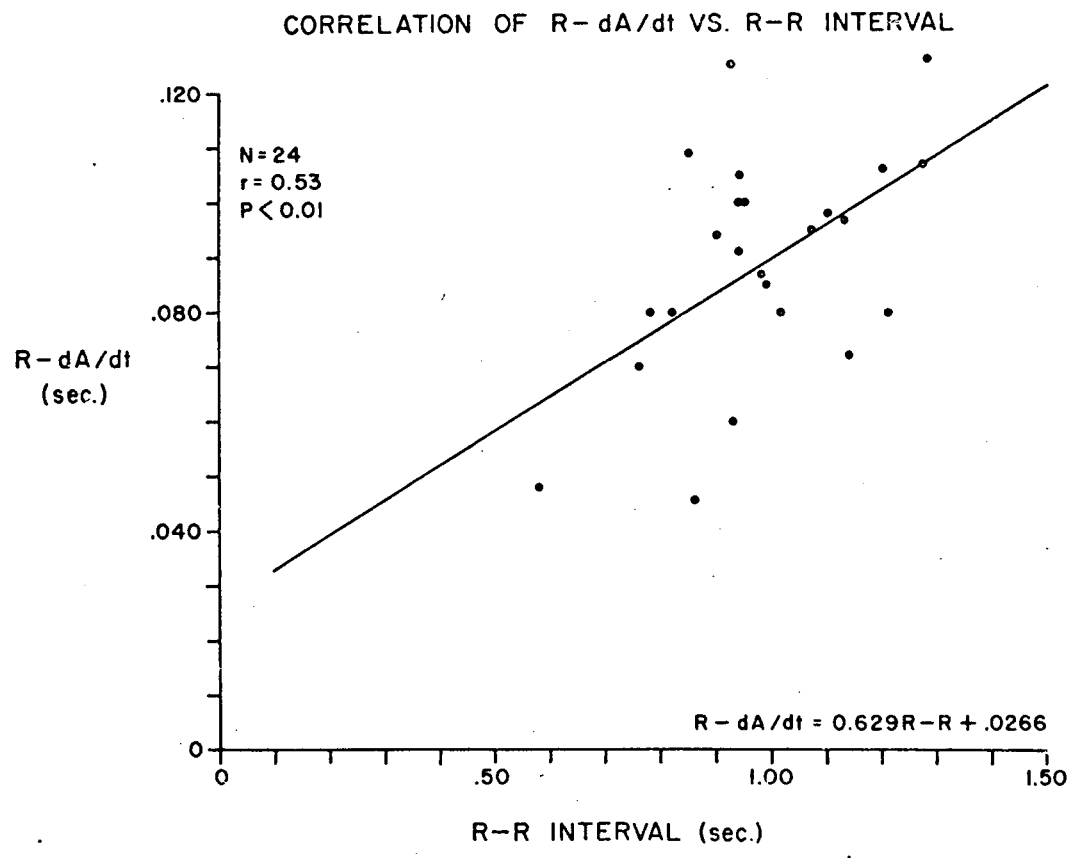

CORRELATION OF R-dA/dt VS. R-R INTERVAL
N=24
r=0.53
P<0.01
R-dA/dt = 0.629R-R + .0266
R-dA/dt (sec.)
.120
.080
.040
0
0
.50
1.00
1.50
R-R INTERVAL (sec.)

FIGURE 3

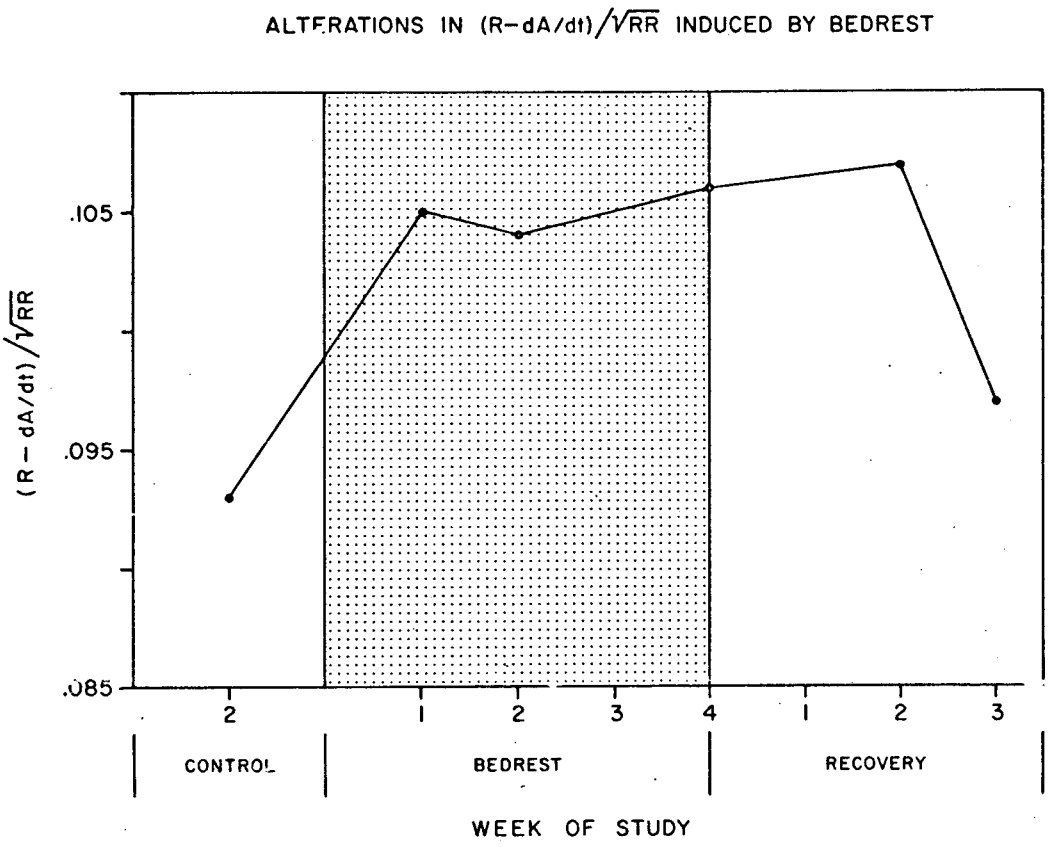

ALTERATIONS IN (R-dA/dt)/√RR INDUCED BY BEDREST
(R - dA/dt)/√RR
.105
.095
.085
2
1
2
3
4
1
2
3
CONTROL
BEDREST
RECOVERY
WEEK OF STUDY

FIGURE 4

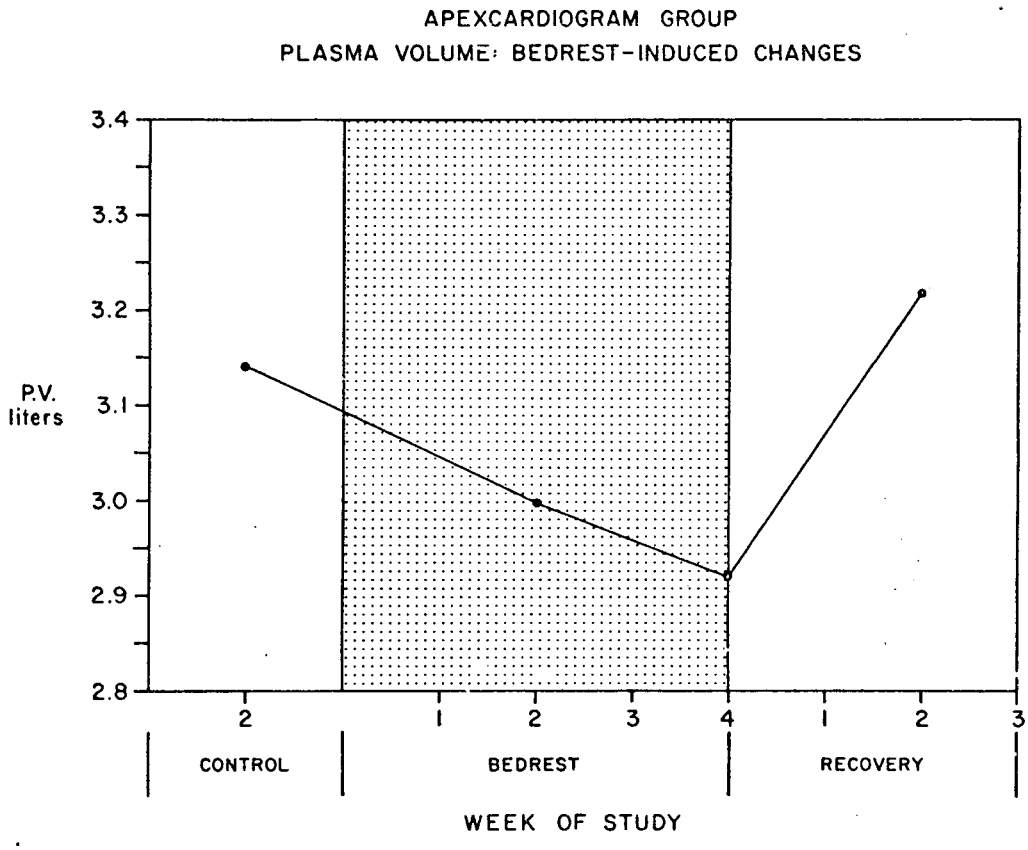

APEXCARDIOGRAM GROUP
PLASMA VOLUME: BEDREST-INDUCED CHANGES
P.V. liters
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2
1
2
3
4
1
2
3
CONTROL
BEDREST
RECOVERY
WEEK OF STUDY

FIGURE 5

ALTERATIONS IN SYSTOLIC TIME INTERVALS
INDUCED BY BEDREST

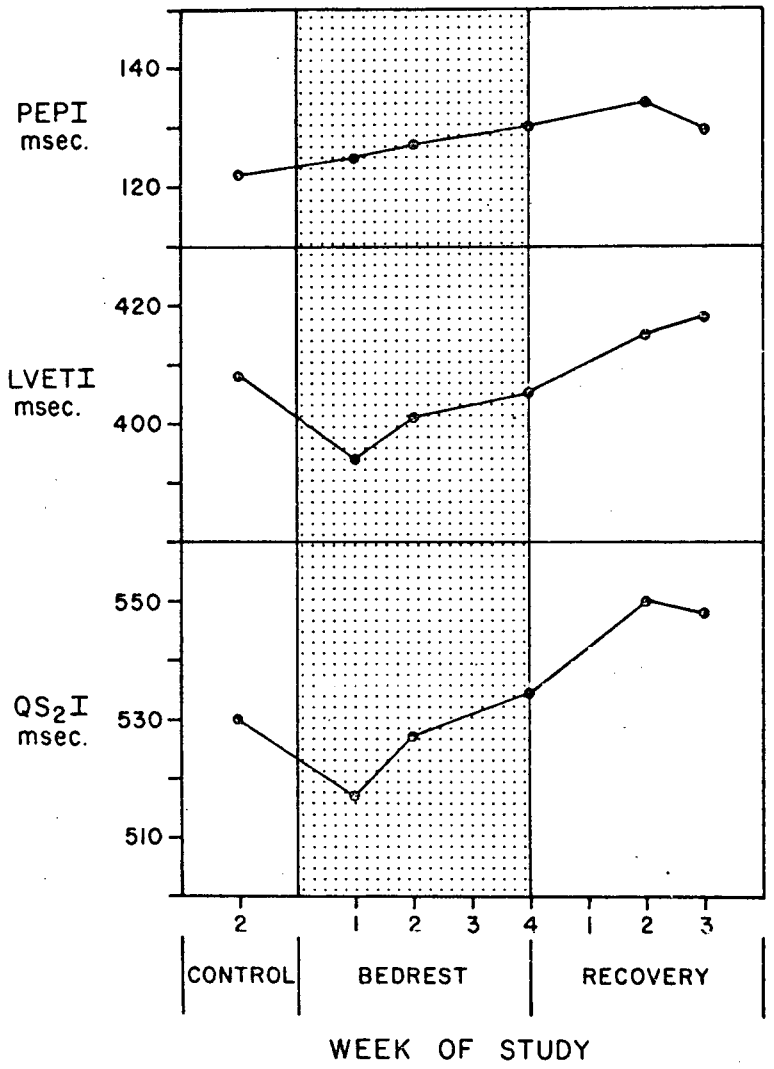


FIGURE 6

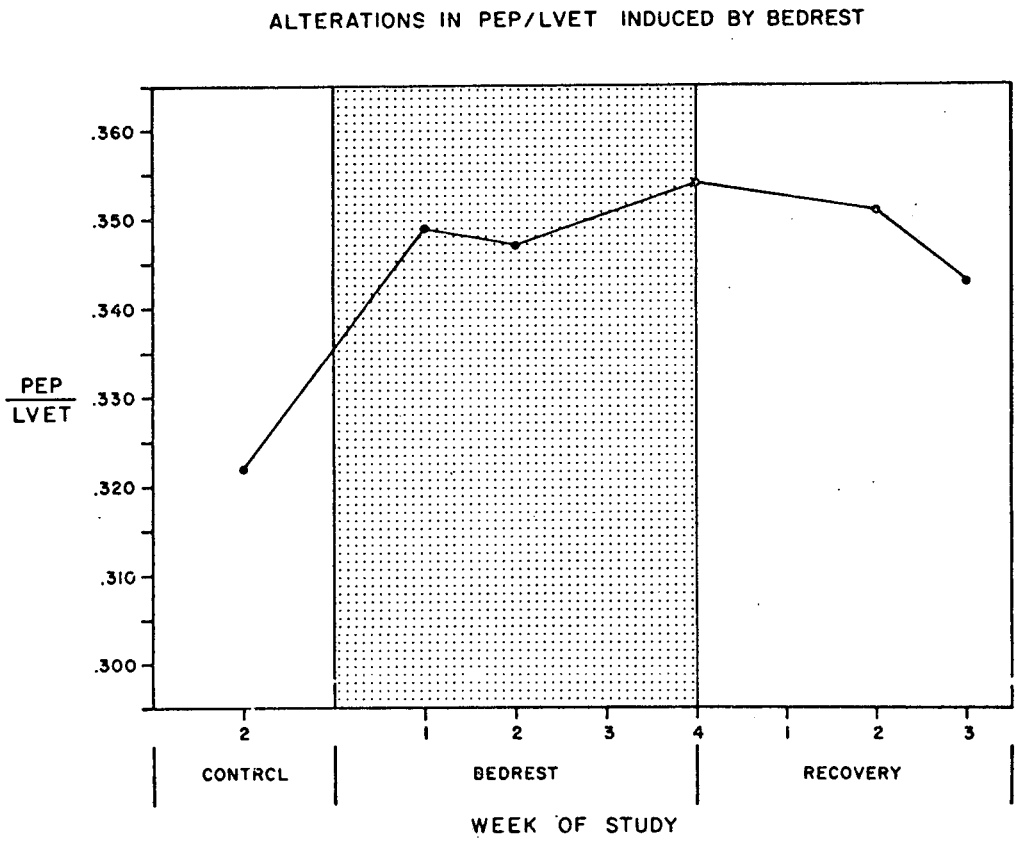
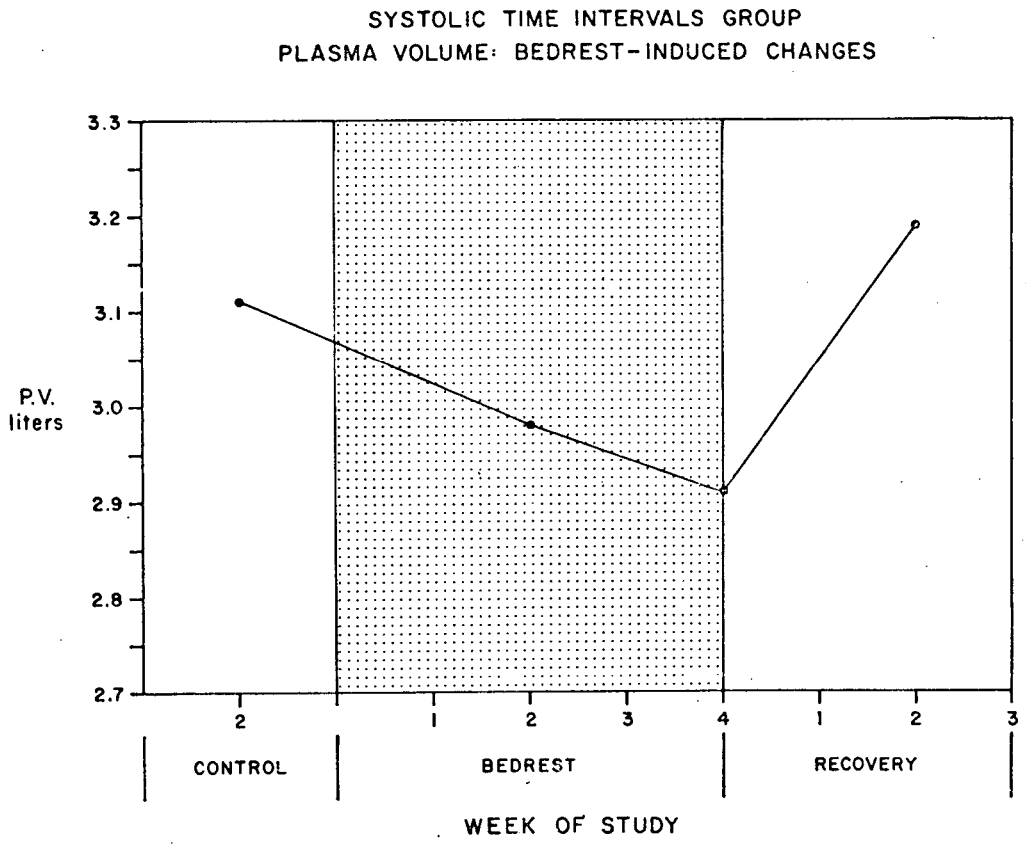

ALTERATIONS IN PEP/LVET INDUCED BY BEDREST
PEP/LVET
.360
.350
.340
.330
.320
.310
.300
2
1
2
3
4
1
2
3
CONTRCL
BEDREST
RECOVERY
WEEK OF STUDY

FIGURE 7


SYSTOLIC TIME INTERVALS GROUP
PLASMA VOLUME: BEDREST-INDUCED CHANGES
P.V.
liters
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2
1
2
3
4
1
2
3
CONTROL
BEDREST
RECOVERY
WEEK OF STUDY